PCT/NZ2004/000234

REC'D 18 OCT 2004
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CERTIFICATE

This certificate is issued in support of an application for Patent registration in a country outside New Zealand pursuant to the Patents Act 1953 and the Regulations thereunder.

I hereby certify that annexed is a true copy of the Provisional Specification as filed on 6 October 2003 with an application for Letters Patent number 528678 made by ENERGY SAVING CONCEPTS LIMITED.

Dated 1 October 2004.

PRIORITY DOCUMENT
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528678

Patents Form No. 4 Our Ref: RC504564

Patents Act 1953

PROVISIONAL SPECIFICATION

A HEAT PUMP AND A METHOD OF OPERATING A HEAT PUMP

We, **ENERGY SAVING CONCEPTS LIMITED,** a New Zealand company, of 8 Lipton Place, Napier, New Zealand, do hereby declare this invention to be described in the following statement:

PT043815397

A HEAT PUMP AND A METHOD OF OPERATING A HEAT PUMP

TECHNICAL FIELD

The present invention relates to heat pump apparatus and to methods of operating a heat pump, and in particular, but not exclusively, to heat pumps which reduce or eliminate icing of the evaporator.

BACKGROUND OF THE INVENTION

The term "heat pump" is used herein to define a device which accepts heat at one or more temperatures and rejects heat at a higher temperature, and which includes, in order, a compressor to pump refrigerant vapor around a closed circuit, a condenser to reject heat from the vapor, thereby condensing the refrigerant, an expansion valve to expand the refrigerant to a gaseous phase, thereby causing the temperature of the refrigerant to fall, and an evaporator to allow the cool refrigerant vapor to absorb heat.

The refrigerant then returns to the compressor and repeats the cycle. Elements such as accumulators and receivers may also be used to ensure that the fluid is in the correct phase before it proceeds around the cycle.

It is to be understood that the term heat pump may be applied equally to such systems when used to remove heat from a space or medium, such as for the purposes of refrigeration, or to systems used for heating a space or medium, such as water or space heating.

Heat pump technology is now very common and many people are starting to understand the savings gained through using this method for heating in addition to its more traditional role in air conditioning. Many Governments and Authorities as well as Industry and Commerce are realizing the benefits. The need to save energy has become a priority around the world.

A disadvantage of using current heat pumps for heating is that ice may form on the evaporator when the ambient temperature around the evaporator drops below a minimum temperature, typically around +10°C. When this happens the efficiency of the heat pump

reduces dramatically due to the low thermal conductivity of the ice reducing the rate at which heat can be absorbed by the evaporator.

One of the options currently used to correct icing of the evaporator is provision of electric heating elements attached to the evaporator or imbedded within it. In such systems the heat pump must be stopped and the refrigerant pumped down to the receiver before the evaporator is heated. Failure to stop the device may lead to liquid refrigerant entering the compressor, which may damage or even destroy it. Once the heat pump has been stopped the heating elements defrost the coil until the ice is melted and the unit can be run again. The heating element may cycle on and off many times until the ambient temperature increases.

A second method in use at present is a hot gas by-pass system. When the evaporator coil ices, a solenoid valve opens and hot gas is directly injected into the evaporator just after the expansion device. This method of evaporator deicing may affect the system's operation dramatically and performance may drop accordingly.

A further method currently is use is to reverse the heat pump so that the functions of the evaporator and condenser are reversed. A disadvantage of this method is that the heat transfer path is reversed, and the element which the heat pump is intended to heat is instead cooled for the duration of the de-icing cycle.

OBJECT OF THE INVENTION

It is an object of a preferred embodiment of the present invention to provide a heat pump apparatus and/or a method of operating a heat pump which will overcome or ameliorate problems with such apparatus or methods at present.

Other objects of the present invention may become apparent from the following description, which is given by way of example only.

SUMMARY OF THE INVENTION

According to a first aspect of the present invention there is provided a heat pump apparatus including an evaporator means, a control means in communication with at least

one sensor means adapted to measure one or more variables representative of a temperature of an outer surface of said evaporator means, and a heat exchanger means operable to add heat from a working fluid from a high pressure side of said heat pump apparatus to working fluid entering said evaporator, wherein said control means operates said heat exchanger means to add said heat when said control means determines that said temperature of said outer surface of said evaporator means is below a preselected temperature, thereby reducing or substantially eliminating formation of ice on said outer surface of said evaporator.

Preferably, said at least one sensor means may include a temperature sensor adapted to measure the temperature of said outer surface of said evaporator.

Preferably, said at least one sensor means may include a temperature sensor adapted to measure the temperature of the working fluid exiting the evaporator.

Preferably, said at least one sensor means may include a temperature sensor adapted to measure the temperature of the environment surrounding the evaporator.

Preferably, said at least one sensor means may include a pressure sensor adapted to measure the pressure of the working fluid exiting the evaporator.

Preferably, said heat exchanger means may include an electric heating element.

Preferably, said heat exchanger means may transfer heat from working fluid between said compressor and said condenser to working fluid entering said evaporator.

Preferably, said preselected temperature may be between 4°C and 0°C.

According to a second aspect of the present invention there is provided a heat pump apparatus including an evaporator means, a control means in communication with at least one sensor means adapted to measure one or more variables representative of a temperature of an outer surface of said evaporator means, and a heat exchanger means including a heating element positioned upstream of said evaporator means and downstream of an expansion device of said heat pump, the heat exchanger means operable to add heat to a working fluid entering said evaporator, wherein said control means operates said heat exchanger means when control means determines that said

temperature of said outer surface of said evaporator means is below a preselected temperature, thereby reducing or substantially eliminating formation of ice on said outer surface of said evaporator.

Preferably, said at least one sensor means may include a temperature sensor adapted to measure the temperature of said outer surface of said evaporator.

Preferably, said at least one sensor means may include a temperature sensor adapted to measure the temperature of the working fluid exiting the evaporator.

Preferably, said at least one sensor means may include a temperature sensor adapted to measure the temperature of the environment surrounding the evaporator.

Preferably, said at least one sensor means may include a pressure sensor adapted to measure the pressure of the working fluid exiting the evaporator..

Preferably, said heat exchanger means may transfer heat from the working fluid on the high pressure side of said heat pump apparatus to the working fluid entering said evaporator.

Preferably, said heat exchanger means may transfer heat from the working fluid between said compressor and said condenser to the working fluid entering said evaporator.

Preferably, said working fluid may be returned to between said condenser and said expansion device after it has passed through said heat exchanger.

Preferably, said preselected temperature may be between 4°C and 0°C.

According to a third aspect of the present invention there is provided a method of operating a heat pump having an evaporator downstream of an expansion device, the method including adding heat from working fluid from a high pressure side of said heat pump to working fluid from a low pressure side of said heat pump, prior to said working fluid entering said evaporator, as required to substantially prevent ice from forming on an outer surface of said evaporator.

Preferably, the method may include measuring one or more variables representative of a temperature of an outer surface of said evaporator means and adding said heat to the working fluid entering said evaporator when said one or more variables indicate that said temperature has dropped below a preselected minimum.

Preferably, the method may include providing a controller to determine when icing of said evaporator is imminent based on said measurements of said one or more variables.

Preferably, the method may include heating the working fluid entering said evaporator with an electric heating element.

Preferably, the method may include heating the working fluid entering the evaporator with heat from said working fluid between said compressor and said condenser.

Preferably, the method may include adding said heat to said working fluid while said heat pump is in operation.

According to a fourth aspect of the present invention, a heat pump and/or a method of operating a heat pump is substantially as herein described with reference to the accompanying drawings.

Further aspects of the present invention, which should be considered in all its novel aspects, will become apparent from the following description, given by way of example only and with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1: Is a schematic diagram of a heat pump apparatus according to one possible embodiment of the present invention.

FIGURE 2a: Is a very diagrammatic cross-sectional view through a heat exchanger and heating element according to one possible embodiment of the present

invention, with the spacing between the corrugated conduit and the outer layer of the heating element exaggerated for clarity.

FIGURE 2b: Is a very diagrammatic cross-sectional view through a heat exchanger and heating element according to another possible embodiment of the present invention.

FIGURE 3: Is a schematic diagram of a heat pump apparatus according to a further possible embodiment of the present invention, with two alternative flow paths for the refrigerant shown.

BRIEF DESCRIPTION OF POSSIBLE EMBODIMENTS OF THE INVENTION

Referring first to Figure 1, a heat pump apparatus in accordance with one possible embodiment of the present invention is generally referenced 100. The heat pump 100 is illustrated with reference to its use as a heating circuit for heating water, but it is to be appreciated that the invention may also be used in applications where refrigeration or air conditioning are required.

The heat pump includes a compressor 1, condenser 2, an expansion device, for example an expansion valve 3, and an evaporator 4, in the same order and performing the same functions as those of the heat pumps of the prior art. A receiver and/or accumulator (not shown) may also be present as required. The condenser 2 rejects heat to a suitable sink, for example a domestic hot water supply 5.

References herein to the "high pressure" side of the heat pump refer to that part of the circuit which the working fluid or "refrigerant" passes through between the compressor 1 and the expansion valve 3. References to the "low pressure" side of the heat pump refer to the remainder of the heat pump circuit.

According to one embodiment of the present invention the heat pump 100 further includes a heat exchanger 6 which may be located immediately downstream of the expansion valve 3 and upstream of the evaporator 4.

A controller 8, for example a computer or microprocessor, but more preferably a Programmable Logic Controller (PLC), may monitor one or more variables which allow it

to predict that icing of the evaporator 4 is about to occur. Preferably, icing may be predicted by a determining that the temperature of an exterior surface of the evaporator 4 is below a predetermined temperature, for example between 4°C and 0°C.

The temperature of the exterior surface of the evaporator 4 may be determined by direct measurement or may be calculated through measurements of other variables, for example through use of a lookup table.

The variables measured may include one or more of the temperature of the ambient air around the evaporator 4, the temperature of the refrigerant leaving the evaporator 4, the surface temperature of the evaporator 4 or the pressure of the refrigerant leaving the evaporator 4. Other variables may also be monitored as will be apparent to those skilled in the art. Figure 1 shows a sensor 10 monitoring the temperature of the refrigerant leaving the evaporator 4 and communicating information related to the temperature to the controller 8.

When the variables sensed by the controller 8 are indicative of a state in which ice may form on the evaporator 4, that is, on an exterior surface of the evaporator coils (not shown), the controller 8 may activate the electric heating element 7, thereby heating the refrigerant entering the evaporator 4. This may be continued until the variables sensed by the controller 8 reach a threshold at which ice formation is no longer likely. At this point the controller 8 may switch the heating element 7 off. The controller 8 may continue to monitor the variables and may continue to switch the heating element 7 on and off as required.

Heating the refrigerant in this way may avoid icing of the evaporator 4 without the need stop the heat pump 100. Those skilled in the art will appreciate that at least a portion of the energy added to the system by the heating element 7 may be recovered as heat from the condenser 2.

Referring next to Figure 2a, as will be known to those skilled in the art, a typical electric element 7 includes a resistive element 12, a heat conducting but electrically resistive material 13 surrounding the resistive element 12, and a outer layer 14. In the heat exchanger 6 of the present invention a helically corrugated conduit 15 may be formed over the outer layer 14 in sufficiently close contact to allow conduction of heat from the outer layer 14 to the conduit 15. The helically corrugated conduit 15 may preferably

be formed using the method described in the Applicant's PCT specification WO 94/07071, and may improve the exchange of heat between the element 7 and the refrigerant 16.

In an alternative embodiment of the present invention, as illustrated in Figure 2b, a corrugated layer 15 may replace the outer layer 14.

Referring next to Figure 3, a second possible embodiment of the heat pump is shown generally referenced by arrow 200, with similar reference numerals used for similar features.

The heat pump 200 also includes a heat exchanger 6a and a controller 8. The controller 8 may sense the pressure in the compressor suction line 9 with a pressure sensor 11, although other variables may additionally or alternatively be sensed as described above.

When the pressure in the suction line 9 falls below a preselected minimum, the controller 8 may allow hot refrigerant from the high pressure side of the heat pump to flow through an intake pipe 17 to the heat exchanger 6a, thereby heating the refrigerant immediately upstream of the evaporator 4 and preventing ice from forming on the evaporator 4.

The hot refrigerant may be taken from anywhere on the high pressure side of the cycle, but preferably from between the compressor 1 and condenser 2, where the refrigerant is at its highest temperature. The hot fluid is preferably returned via an outlet pipe 18 to the downstream side of the condenser 2 after passing through the heat exchanger 6a, although in some embodiments the fluid may be returned to substantially the same point in the cycle after passing through the heat exchanger 6a, as illustrated by outlet pipe 18a.

When the controller 8 determines that icing is no longer imminent the flow of hot refrigerant to the heat exchanger 6a may be ceased to allow the apparatus 200 to perform at maximum efficiency. In a preferred embodiment the controller 8 may be a simple mechanical valve which is activated by changes in the pressure of the compressor suction line 9.

Those skilled in the art will appreciate that the embodiments shown in Figures 1 and 3 may be combined as necessary, and the controller 8 may determine whether to use either heating method alone or both in combination.

Those skilled in the art will also appreciate that by preventing ice from forming on the evaporator 4 without stopping the refrigerant flow, the present invention may be more efficient than the heat pumps of the prior art when used in environments where icing of the evaporator may occur, for example those in which the ambient temperature drops below around 10°C.

Where in the foregoing description, reference has been made to specific components or integers of the invention having known equivalents then such equivalents are herein incorporated as if individually set forth.

Although this invention has been described by way of example and with reference to possible embodiments thereof, it is to be understood that modifications or improvements may be made thereto without departing from the spirit or scope of the invention.

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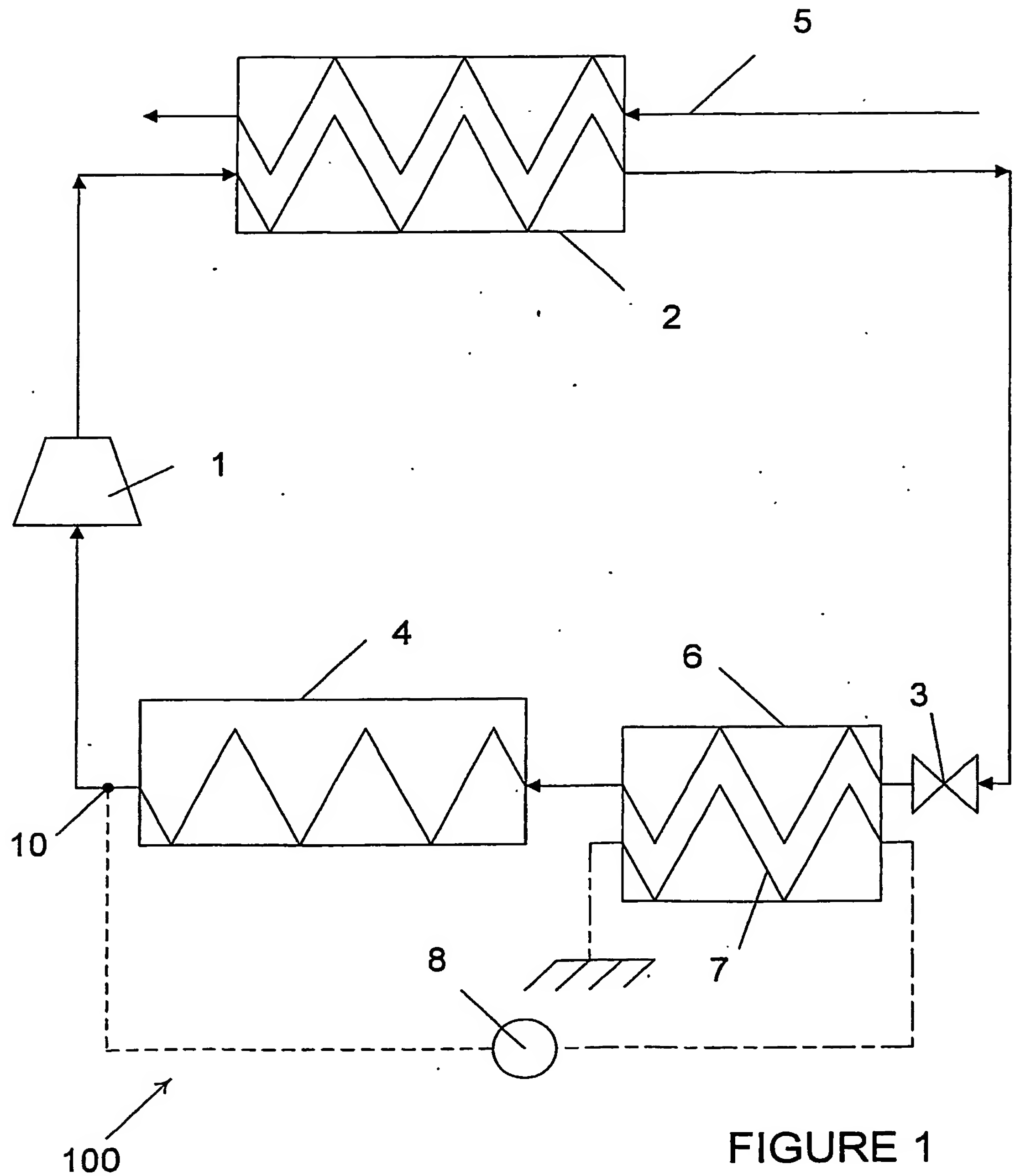

FIGURE 1

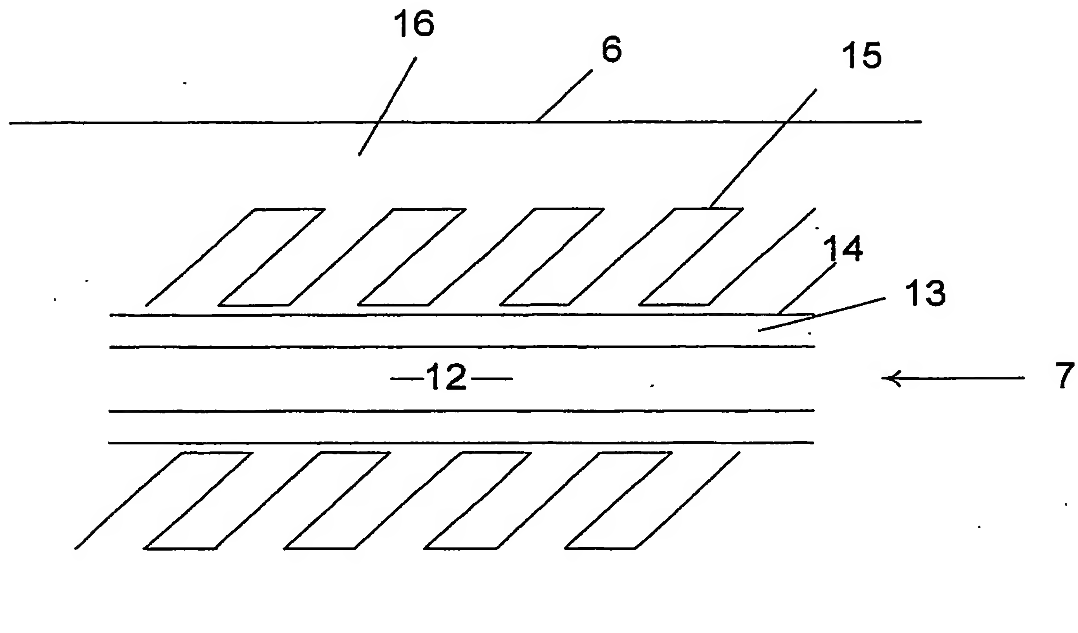

FIGURE 2a

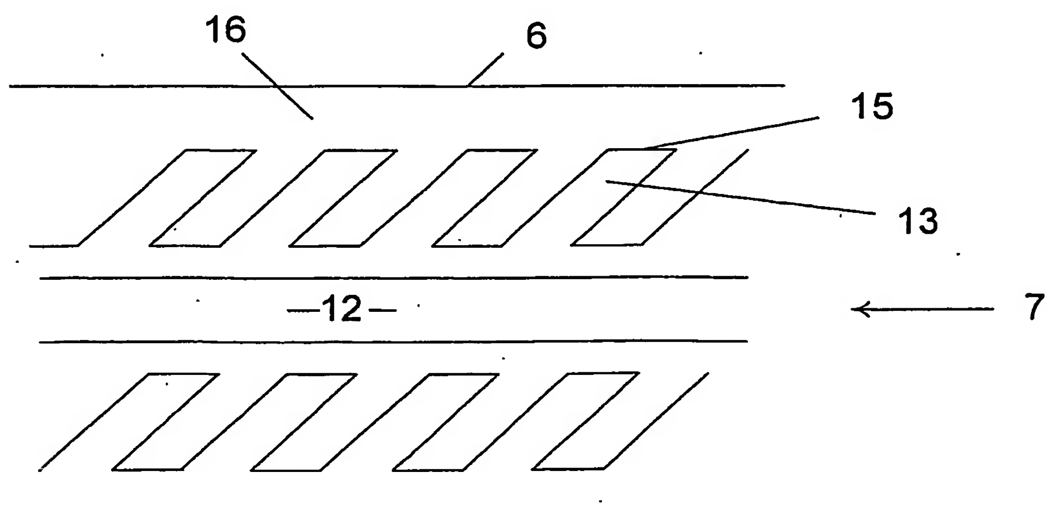

FIGURE 2b

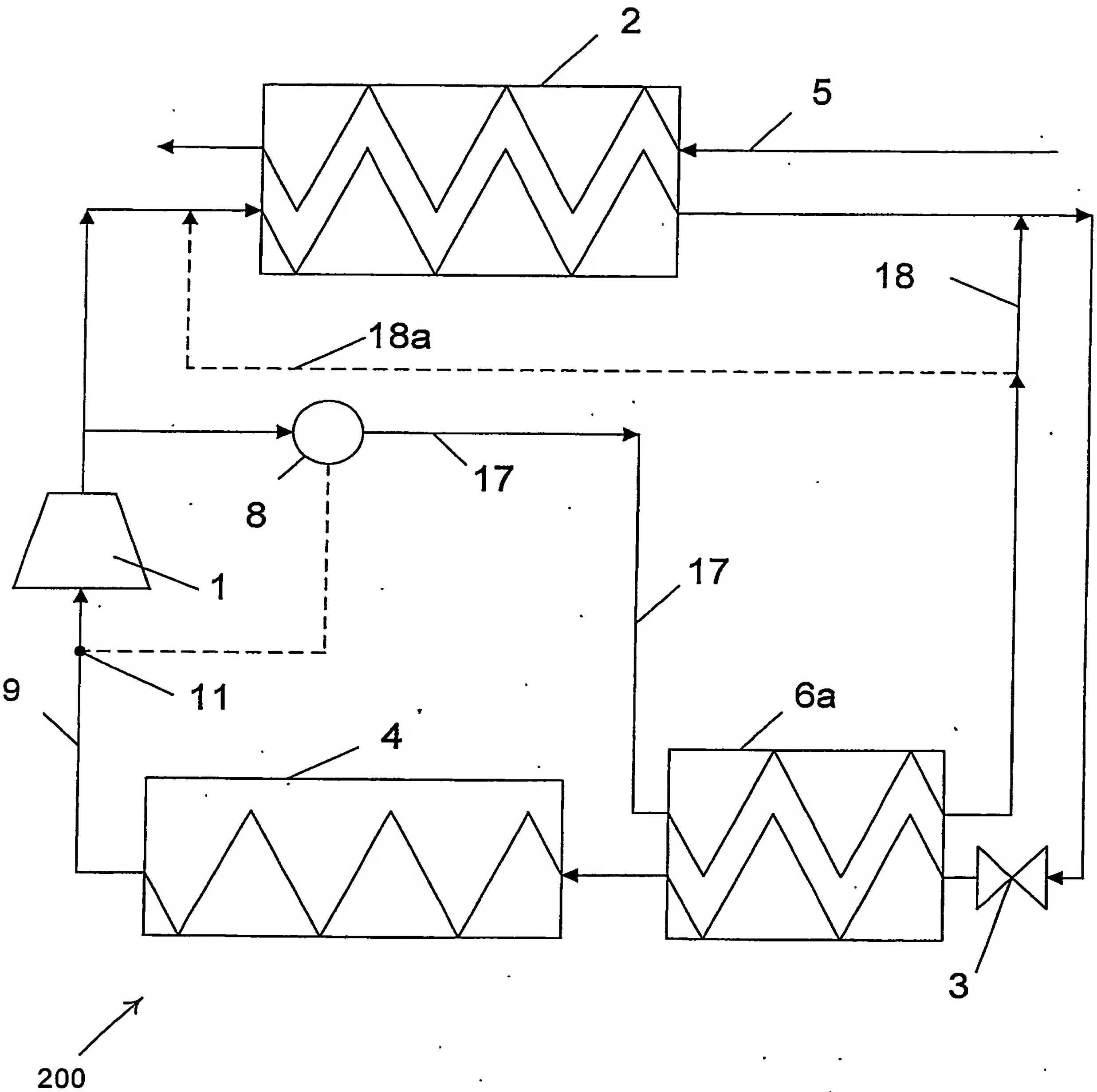

FIGURE 3